Karlsruhe Institute of Technology

Institute for Industrial Production

Sector Coupling in Energy Transition

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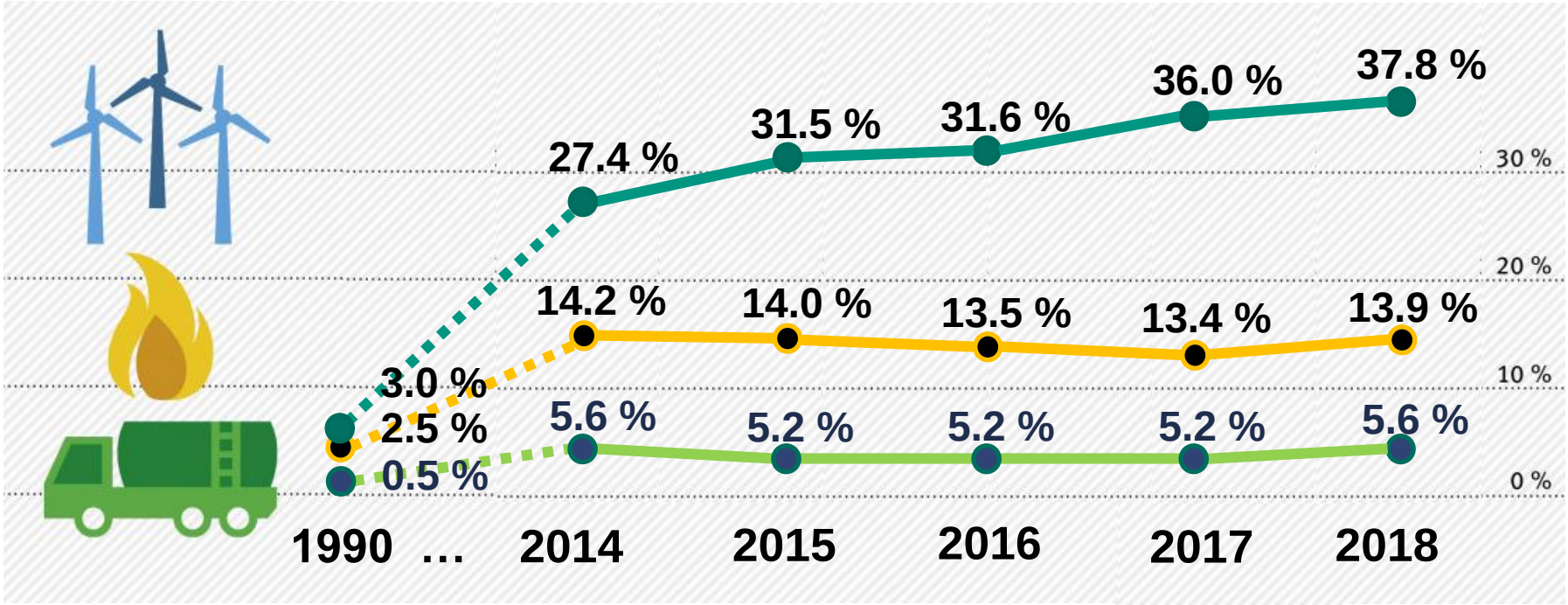
Why do we need a Sector Coupling?

Renewable share in the German power, heat and transport sector:



source: Umweltbundesamt auf Basis Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)

Sector coupling enables expansion of **renewables to the other sectors,** to deacrbonise these sectors and use storage options there

Defining Sector Coupling

Two types of sector coupling:

- **“End-use sector coupling** involves the electrification of energy demand while reinforcing the interaction between electricity supply and end-use.”

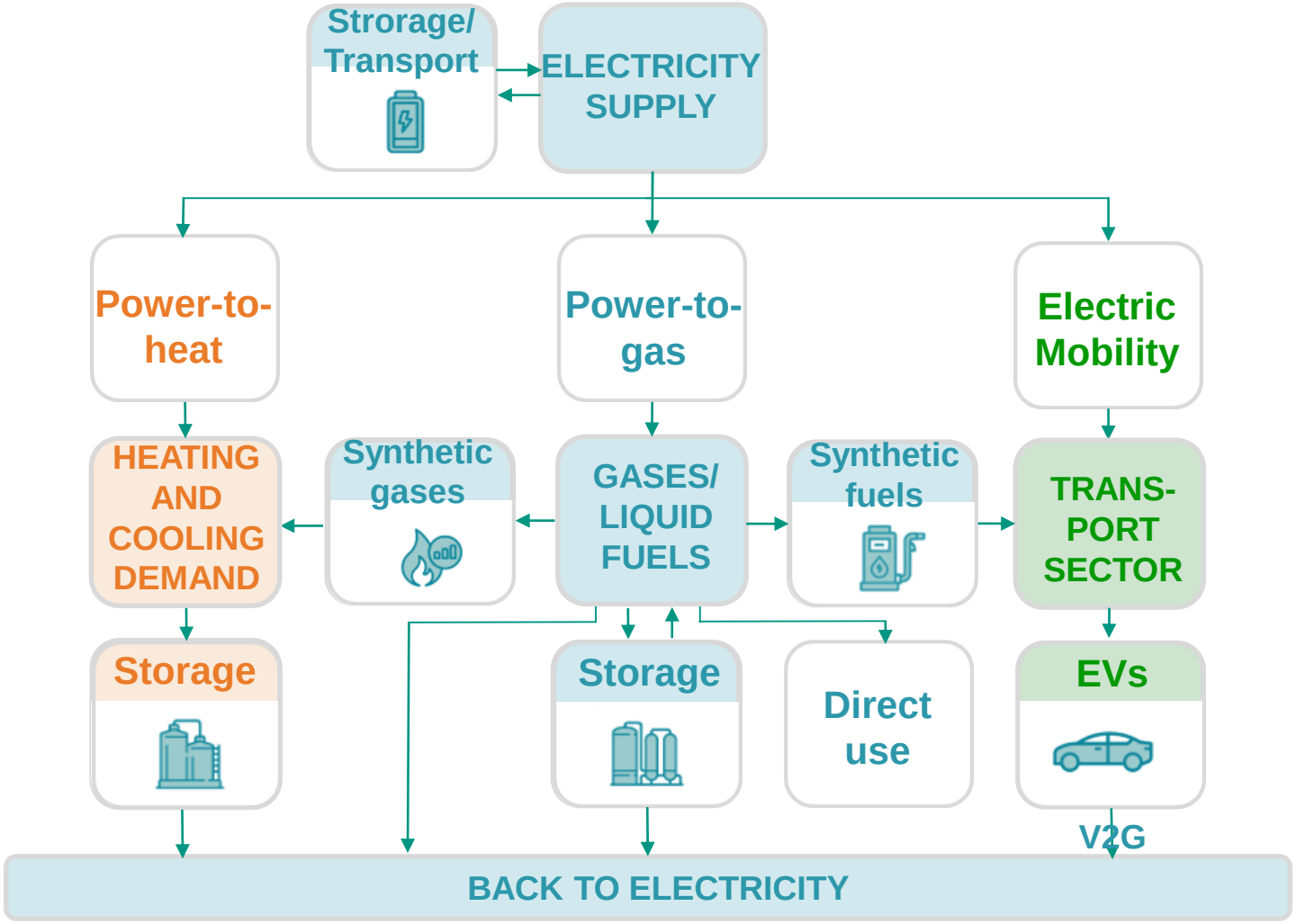
- **“Cross-vector coupling** involves the integrated use of different energy infrastructures and vectors, in particular electricity, heat and gas, either on the supply side, e.g. through conversion of (surplus) electricity to hydrogen, or at the demand side, e.g. by using residual heat from power generation or industrial processes for district heating.”

(DG for Internal Policies, European Parliament, Nov. 2018)

Alternative terms (UK, EERA-European Energy Research Alliance):

„Energy Vector Coupling“ or „Energy Systems Integration“

Different ways of Sector Coupling

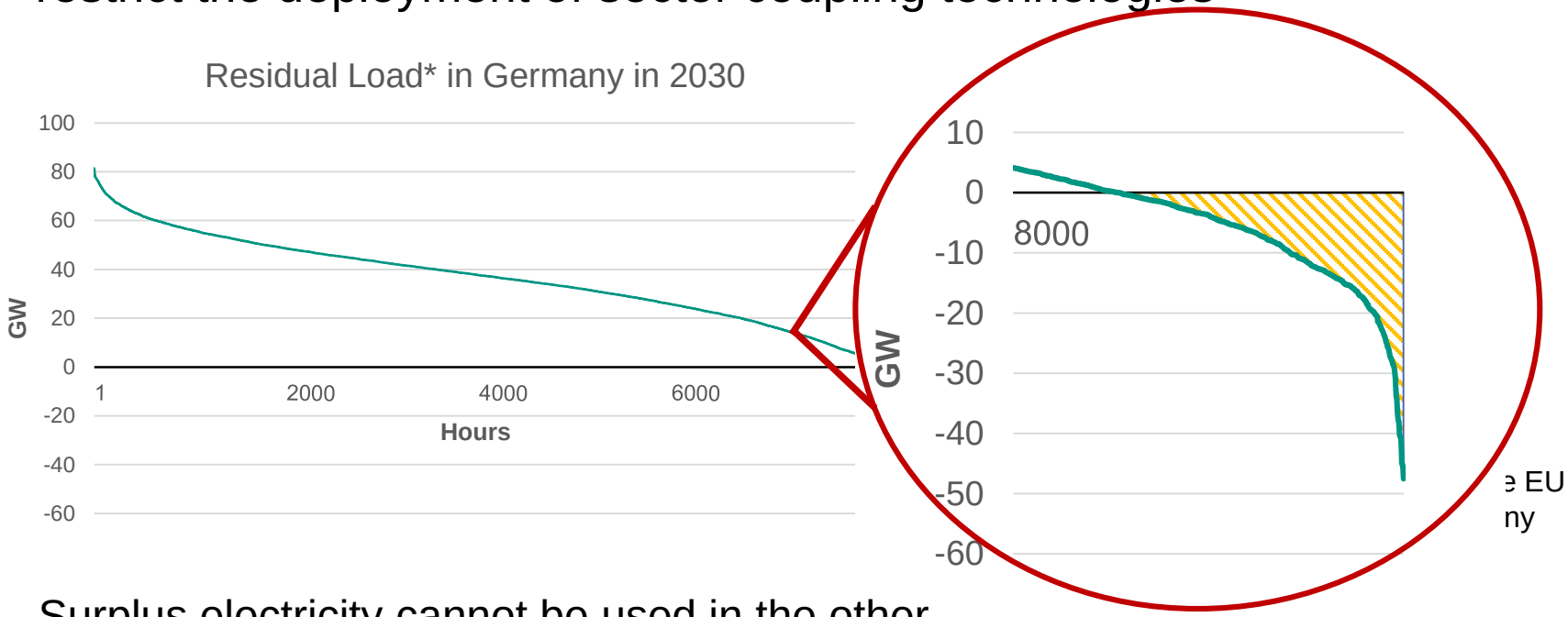


Source: IEA, 2019

Barriers to Sector Coupling

1. Several sector coupling technologies are not yet competitive in terms of cost and performance

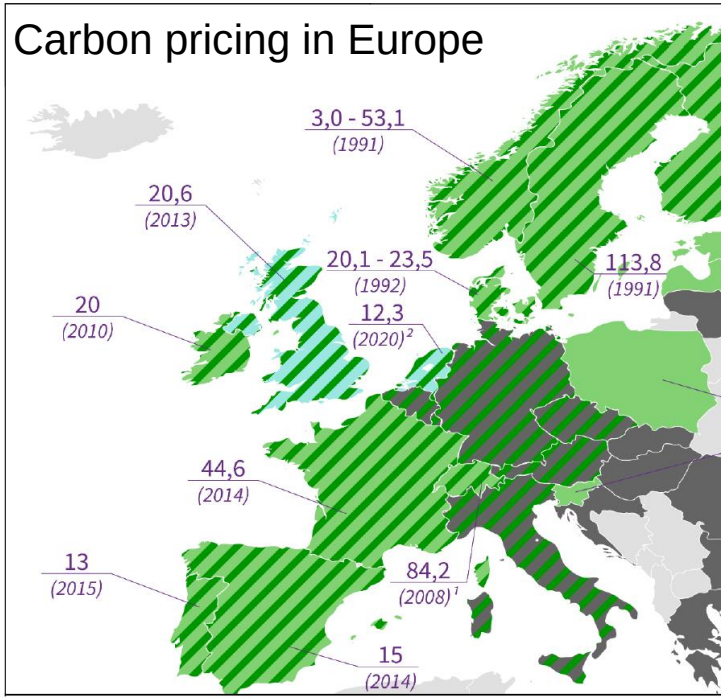
2. Market regulations, such as taxes and charges on end-user prices, restrict the deployment of sector coupling technologies



Surplus electricity cannot be used in the other sectors, even if p_{el} is „0 €/MWh“: $c_{grid} + c_{RES} > p_{heat}$

Barriers to Sector Coupling

3. Lack of adequate carbon pricing in the heat and transport sector

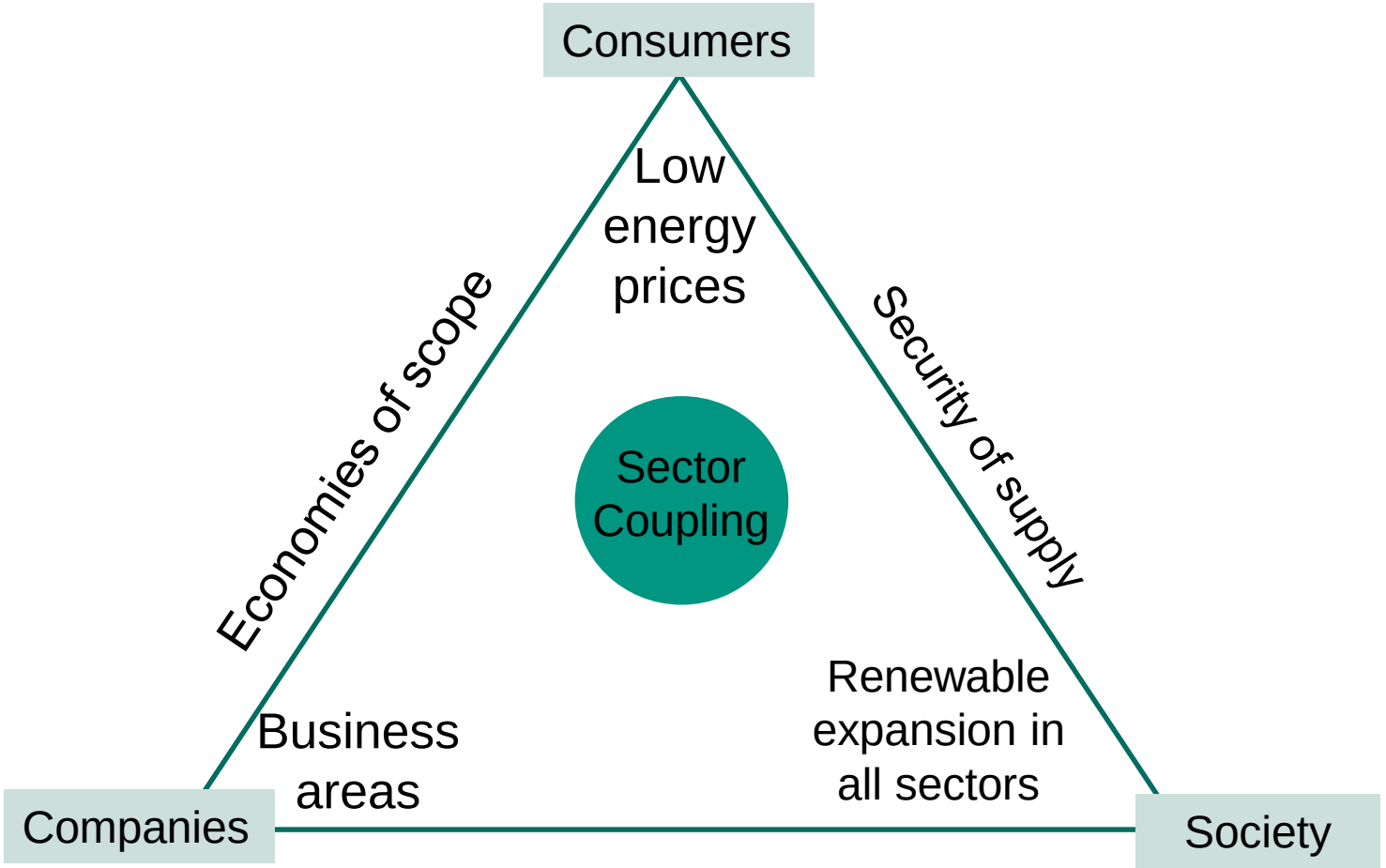


EU-ETS covers electricity sector and aviation, but not heat and mobility sector

Additional taxes in some European countries (CH, SE)

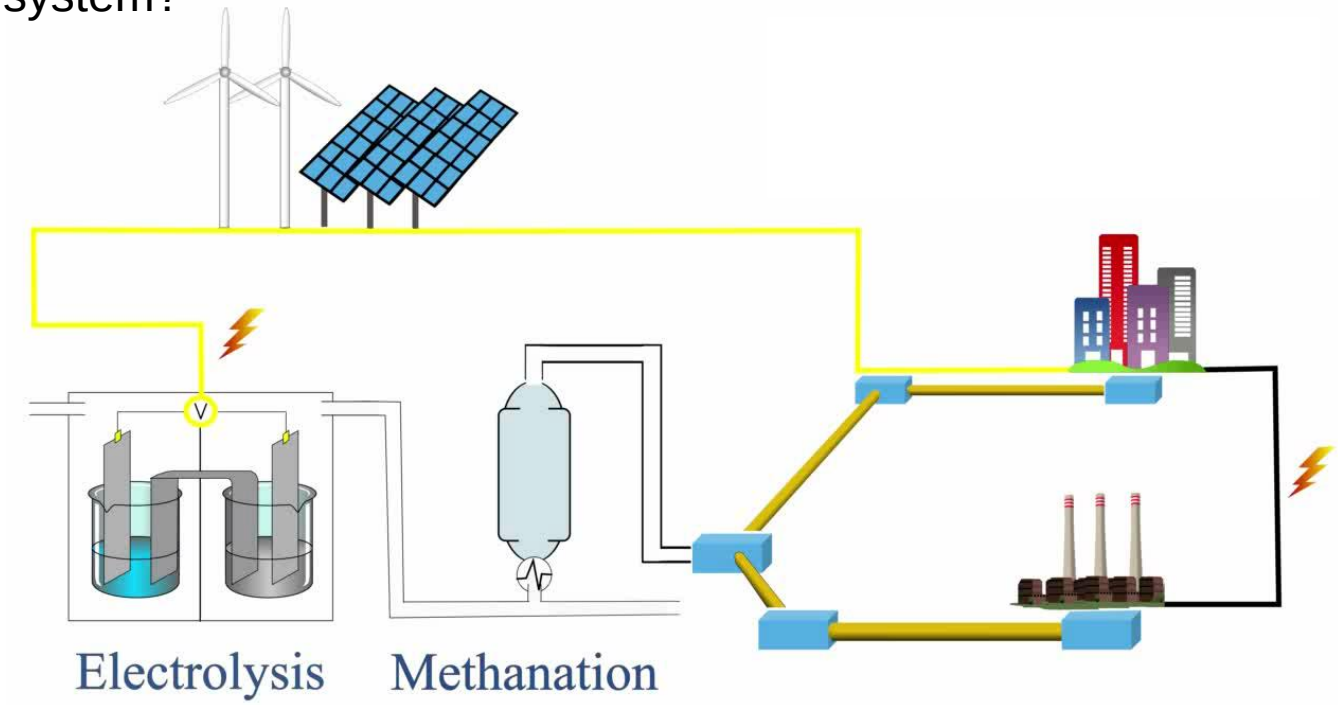
Source: Germanwatch (06/2019)

Benefits of Sector Coupling



Sector Coupling: Power-to-gas

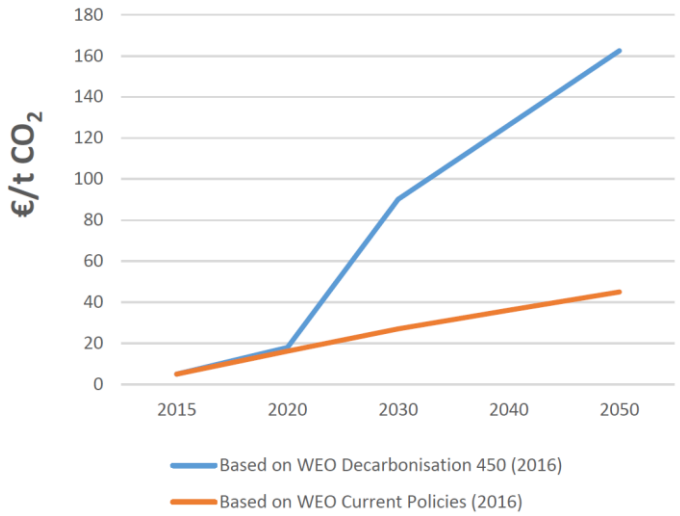
Research question: What is the role of Power-to-gas in decarbonising the energy system?



Src.: Yilmaz, HÜ.; Kimborough, S.; van Dinther, C.; Keles, D. (2020): Carbon Pricing and Power-to-Gas: Keys to the Decarbonization of the European Electricity System, *submitted to Energy Policy*

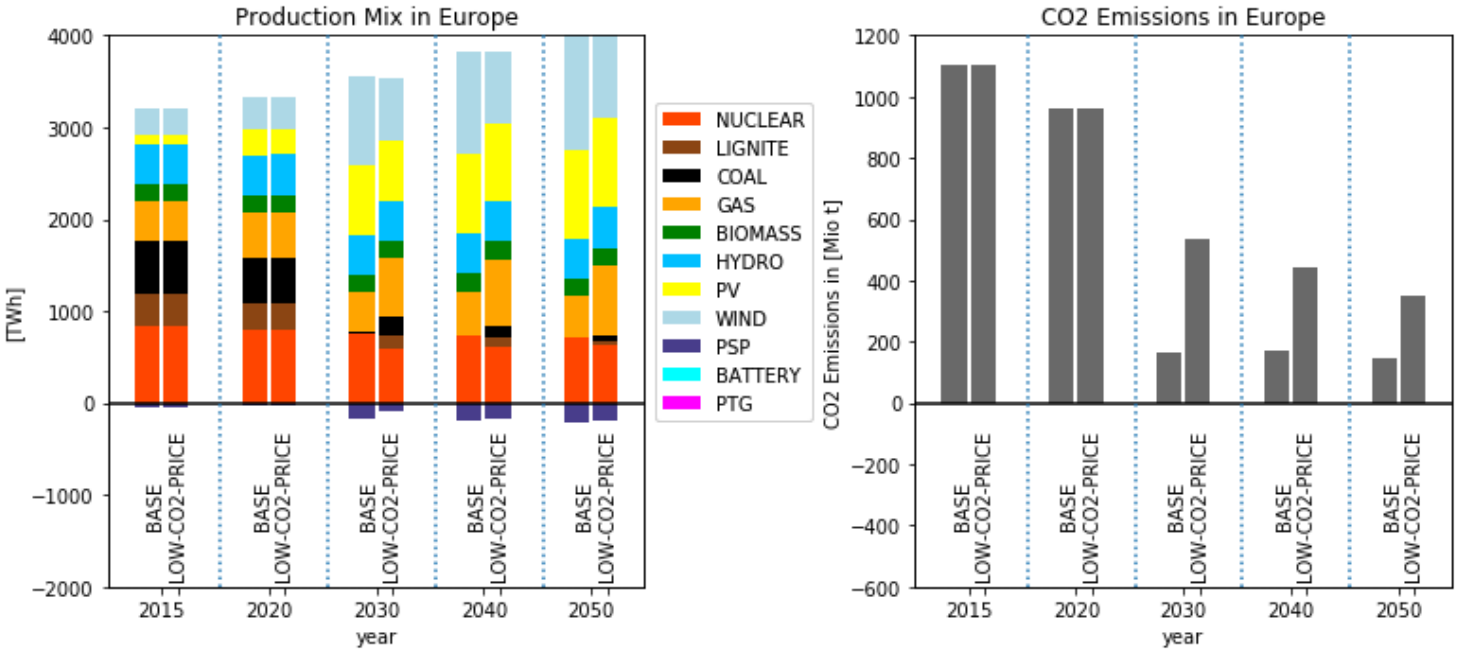
Methodology and Scenarios

- Energy system model PERSEUS-EU
- Investments in coal-fired power plants are not permitted.
  - → Results in EU-Wide coal phase-out
- The scenarios vary on the cost assumptions and storage options.



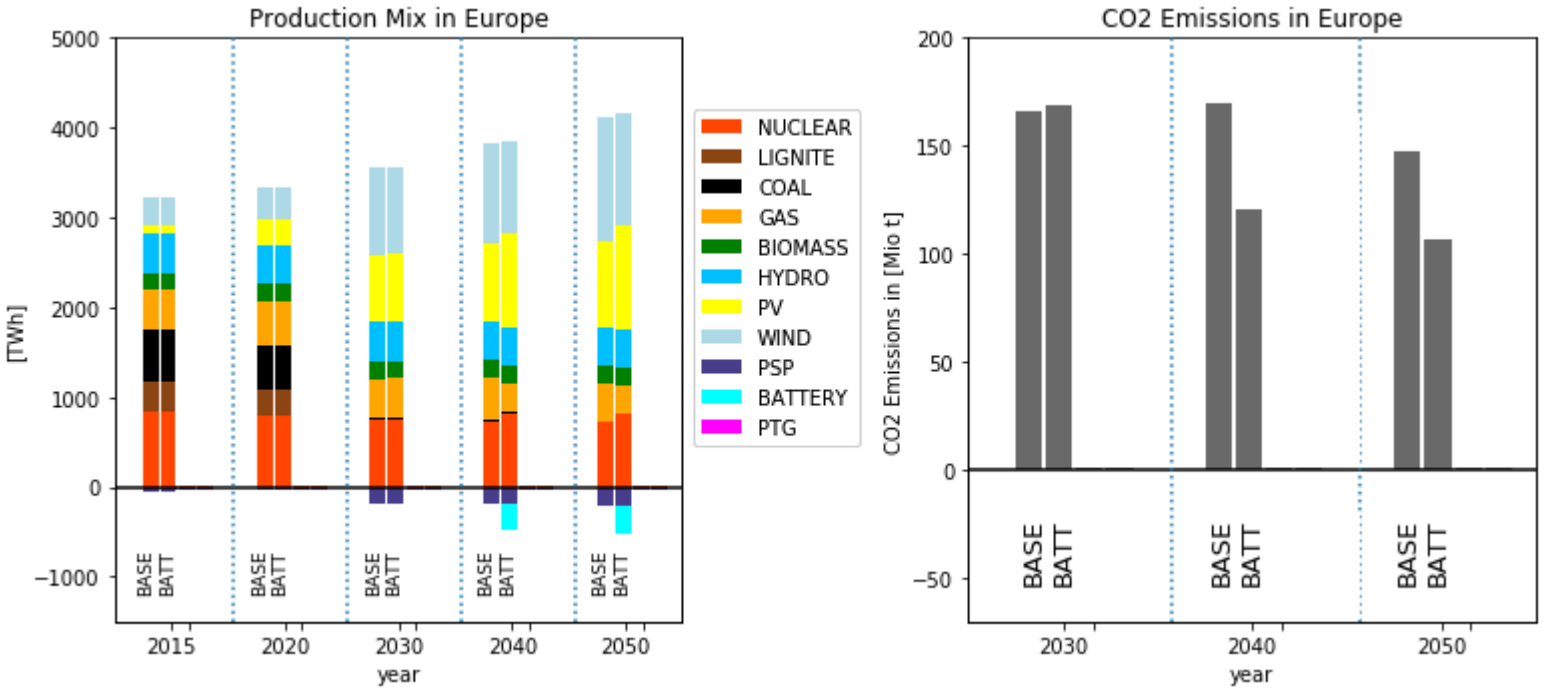
Scenario Names	CO_2 Price	Battery Investments	Power-to-gas investments
LOW-CO2-PRICE	low	Not available	Not available
BASE	high	Not available	Not available
BATT	high	Allowed	Not available
PTG	high	Not available	Allowed
PTG-BATT	high	Allowed	Allowed

Production Mix and Emissions BASE vs. LOW-CO2-PRICE



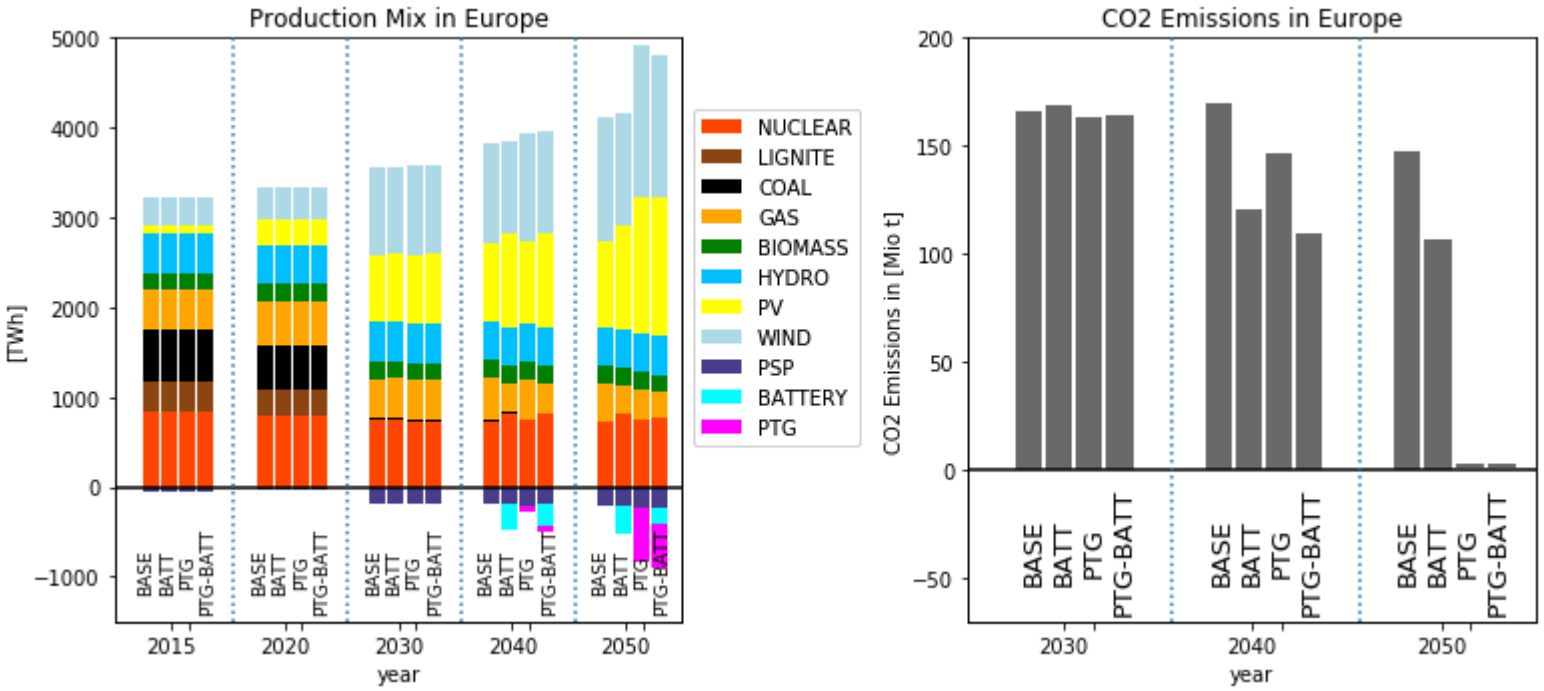
- In both scenarios, CO_2 emissions decrease due to cost reductions in renewable energies, the coal phase-out and high CO_2 prices.
- Emissions are significantly lower in HIGH-CO2-PRICE due to high CO_2 price assumptions.

Production mix and emissions



- In BATT scenario, emissions in 2050 are 30% lower than in the BASE scenario.

Production mix and emissions



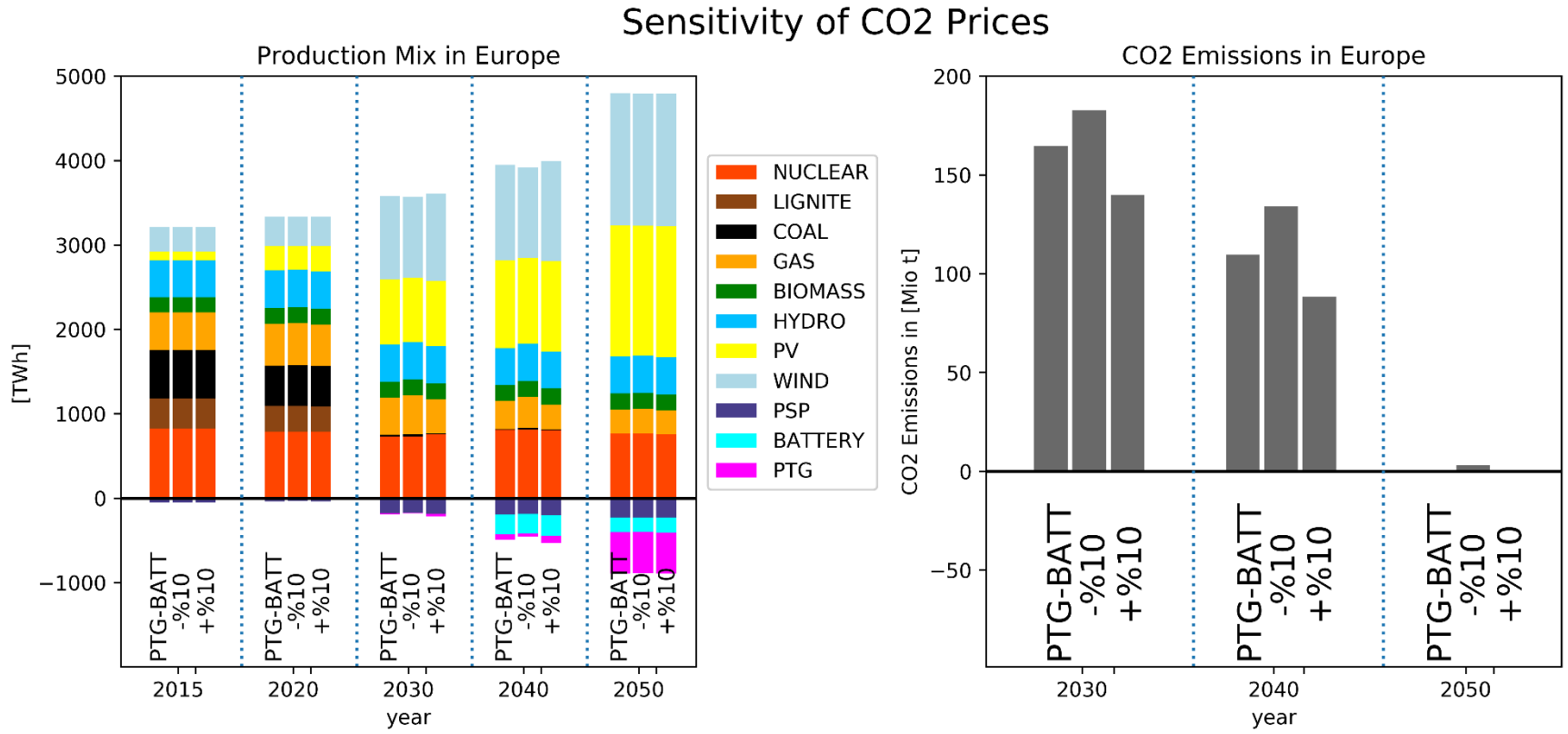
- In BATT scenario, emissions in 2050 are 30% lower than in the BASE scenario.
- In PTG scenario, there is no emissions in 2050.
- In PTG-BATT scenario a part of the synthetic gas is replaced by battery technologies.

Summary

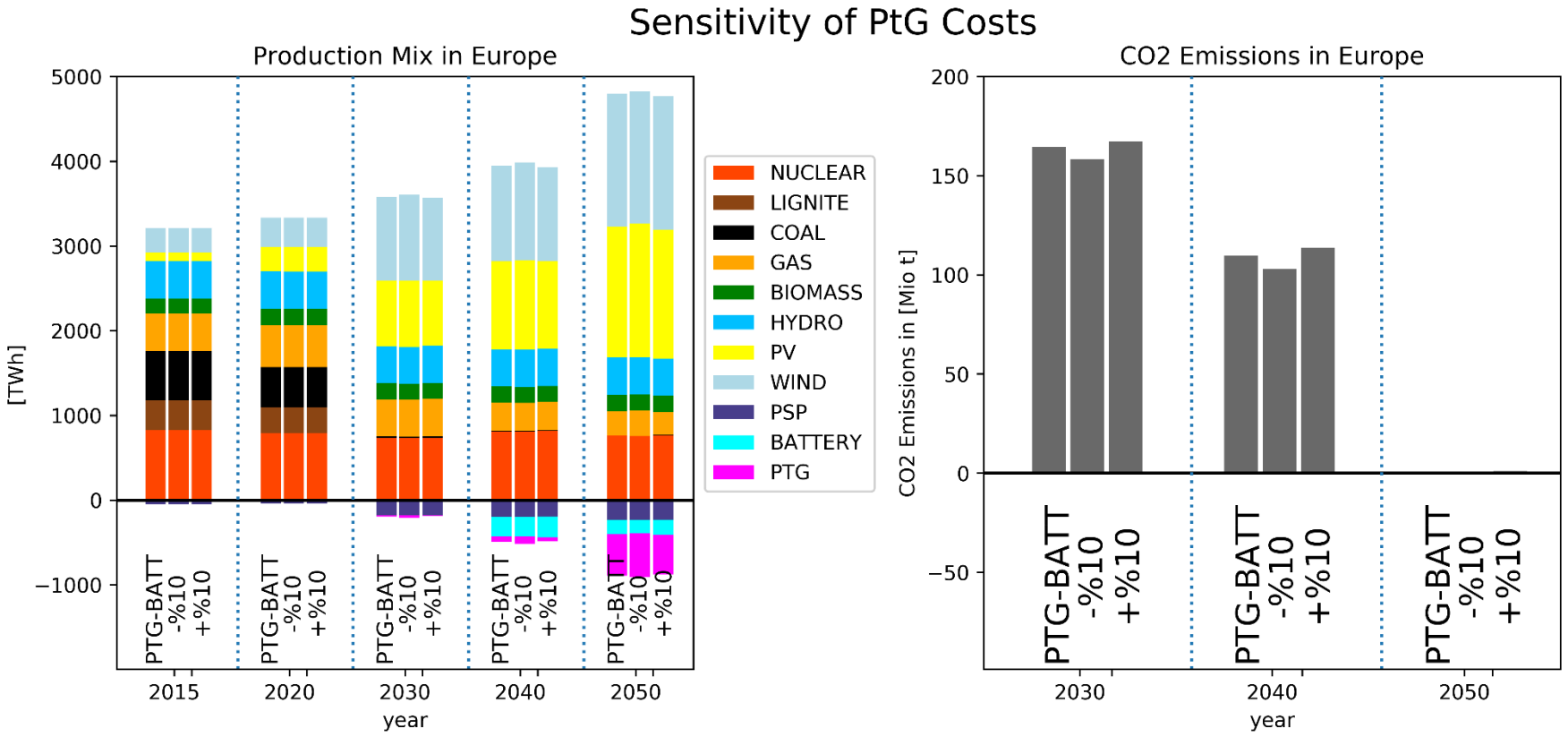
- Reducing GHG emissions requires RES expansion in all sectors
- Definition of sector coupling:
  End-use sector coupling and **Cross-vector coupling**
- Benefits include security of supply, net-zero GHG emissions
- High CO2 prices (125 by 2040, up to 160 €/ton by 2050), combined with PtG leads to an economically feasible decarbonization of the European electricity system by 2050
- Challenges are technological, but mainly economic and regulatory obstacles, such as high share of taxes and fees in end-user prices, but missing efficient carbon pricing

BACKUP

Sensitivity of CO_2 prices



Sensitivity of PtG costs



Enabling Sector Coupling

- Regulatory aspects:
  - Internalization of external costs in all sectors (CO_2-tax?)
  - Funding for sector coupling technologies (entry phase)
  - Support for renewable energies in the heat and transport sector
- Development of IT-networks and smart grids to make demand flexible (heat pumps, electric vehicles)
- R&D to reduce costs of technologies and increase efficiency